Coverage and Performance Evaluation of Home WiFi Network

A Project Report

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THESIS CERTIFICATE

This is to certify that the thesis titled **Coverage and Performance Evaluation of Home WiFi Network** , submitted by **ASHWINI GIRISH CHINTA**, to the Indian Institute of Technology, Madras, for the award of the degree of **Master of Technology** , is a bonafide record of the research work done by her under our supervision. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

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ABSTRACT

KEYWORDS: Home WiFi, Dense Network, IoT

With increase in the Internet of things (IoT) devices, smart home building we need good WiFi coverage in a home. WiFi is one of the key technologies that enable connectivity for smart home services. First part of the thesis deals with with the typical home WiFi coverage for a given AP deployment and recommends the optimal AP location for the best WiFi coverage in home.

The number of internet users are increasing with at an exponential rate. The residential multistoreyed buildings are turning into a dense network with the advent of large number of Access Points and clients . Second part of thesis focuses on apartment building structure of dense network and evaluates the performance of WiFi in dense scenario

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ABBREVIATIONS

WLAN	Wireless Local Area Network
MAC	Medium Access Control
PHY	Physical
CSMA-CD	Carrier sensing multiple access collision detection
RSSI	Received Signal Strength Indicator
TCP	Trasport Control Protocol
UDP	User Datagram Protocol
AP	Access Point
CCA	Clear Channel Assessment

NOTATION

$\mathcal{N}(\mu, \sigma^2)$	Gaussian distribution with mean μ and variance σ^2

CHAPTER 1

Introduction

1.1 Aspects of Wi-Fi

A WiFi is a wireless network which is more correctly wireless LAN (WLAN) i.e Wireless Local Area Network. WiFi is a brand name of WiFi alliance used by industry organization responsible for interoperability testing of equipment.

The IEEE 802.11 standards defines the protocols that enable communication with current Wi-Fi enabled wireless devices,including wireless routers and wireless access points. Wireless access points support different IEEE standards. Each standard is an amendment that was ratified over time. The standards operate on varying frequencies, deliver different bandwidth, and support different numbers of channels.

The IEEE standard focuses mainly on MAC layer and PHY layer of network which is necessary for WLAN. IEEE 802.11 standards has grown from a/b/g/n/ac and now latest is 802.11ax standard.

WiFi operates in 2.4 GHz and 5 GHz frequency band. The 802.11ac can support a maximum data rate of 866 Mbps of data rate and it became possible due to higher modulation , MIMO and OFDM

WiFi operates in unlicensed spectrum which leads to interference from WiFi radio and non WiFi radio so primary channel access mechanism of WiFi is CSMA-CD.
tabbing

1.2 NS-3

NS-3(Network Simulator) is a discrete-event network simulator, which means that the state of the simulation model can only change at discrete points in time, referred to as events. Events are inserted into a queue, each with a specific time. Between the events in the queue nothing is changed. The execution of a event often leads to new scheduled events.

The NS-3 project started in 2006 and is open-source. It is free software under the GNU GPLv2 license. One advantage of NS- 3 is that is written entirely in C++ so there is no need to debug two languages at the same time, as in the case with its predecessor, NS-2. NS-2 was written in C++ and an object oriented extension of the Tool Command Language (TCL). The version used for this project is NS-3.29.

NS-3 nodes can contain a collection of NetDevice objects, much like an actual computer contains separate interface cards for Ethernet, WiFi, Bluetooth, etc.

The NS-3 simulation supports both IP and non-IP based networks.It also supports wireless /IP simulation which involve models of WiFi, LTE or other wireless system for layer 1 and 2.And transport layer protocol such as TCP and UDP. By using real-time scheduler facility of NS-3 we can interact with real time system.

1.2.1 NS-3 WifiNetDevice

By adding WifiNetDevice objects to NS-3 nodes, one can create models of 802.11-based infrastructure and ad hoc networks. NS-3 provides models for these aspects of 802.11.

- Basic 802.11 DCF with infrastructure and ad hoc modes
- 802.11a, 802.11b, 802.11g, 802.11n (both 2.4 and 5 GHz bands), 802.11ac and 802.11ax (both 2.4 and 5 GHz bands) physical layers
- MSDU aggregation and MPDU aggregation extensions of 802.11n, and both can be combined together (two-level aggregation)
- QoS-based EDCA and queuing extensions of 802.11e
- The ability to use different propagation loss models and propagation delay models, please see the chapter on Propagation for more detail

The set of 802.11 models Of NS-3 provides an accurate MAC-level implementation of the 802.11 specification and to provide a packet-level abstraction of the PHY-level for different PHYs, corresponding to 802.11a/b/e/g/n/ac/ax specifications.

WiFi Model of NS-3 is classified in to three major parts

- **PHY layer models:** The physical layer models are mainly responsible for modeling the reception of packets and for tracking energy consumption. There are typically three main components to packet reception

- **MAC layer:** MAC is further divided in to MAC Low and MAC high.
  MAC low: takes care of RTS/CTS/DATA/ACK transactions and also performs MPDU aggregation.
  MAC high: Mac high implements non-time-critical processes in WiFi such as the MAC-level beacon generation, probing, and association state machines, and a set of Rate control algorithms

CHAPTER 2

Coverage Analysis of Home WiFi

This chapter will give an overview of Home WiFi coverage in terms of **RSSI** and **Throughput**. Tje wireless coverage at home is obtained for a specific AP deployment. Coverage analysis of WiFi was studied with three different home structures.

2.1 Building Models

To do the coverage analysis three homes of different dimensions and different number of rooms in home has been used. These building were build using NS-3 Building model to define the dimension of building.A buildings represented as a rectangular parallelopiped in NS-3 and walls are parallel to x, y and z-axis . Building is divided in to grid of rooms and can be identified by number of floors ,number of rooms along the x-axis and number of rooms along the y-axis. The z-axis is the vertical axis represents the number of floors.The x and y room indices start from 1 and increase along the x and y axis respectively and all rooms in a building have equal size.

2.2 Building Mobility Model

Building model gives information about the position of a node with respect to building , whether the node is indoor or outdoor if the node is in indoor in which building the node is and in which room.

2.3 HybridBuildingsPropagationLossModel

NS-3 has several path loss model for indoor and out door scenarios , all those path loss model are incorporated in the Hybrid building propagation loss model. it has following pathloss models.

- OkumuraHataPropagationLossModel (OH) (at frequencies > 2.3 GHz substituted by Kun2600MhzPropagationLossModel)
- ItuR1411LosPropagationLossModel and ItuR1411NlosOverRooftopPropagationLossModel (I1411)
- ItuR1238PropagationLossModel (I1238)
- The pathloss elements of the BuildingsPropagationLossModel (EWL, HG, IWL)

All nodes used in the scenarios were indoor so, the ItuR1238 PropagationLossModel has been used.

2.3.1 ItuR1238PropagationLossModel

Itu-R is the International telecommunication union which is responsible for radio communication. ItuR1238PropagationLossModel gives the equation for pathloss model for different types of building.

$$L_{total} = 20log_{10}(f) + Nlog_{10}(d) + L_f - 28[dB] \tag{2.1}$$

Where

$$N = \begin{cases} 28 & Residential \\ 30 & Office \\ 22 & Commercial \end{cases}$$

$$L_f = \begin{cases} 4n & Residential \\ 15 + 4(n-1) & Office \\ 6 + 3(n-1) & Commercial \end{cases}$$

n:number of floors between AP and client
f:frequency in [MHz]
d:distance in [m]

2.3.2 External wall loss:

The loss gives path loss between outdoor and indoor communication and vice-versa. The loss values are depending upon the type of wall and those values are taken from COST231 model.

2.3.3 Internal wall:

This component gives the penetration loss occurred in indoor-to-indoor communications within the same building. It gives the path loss constant multiplied by number of walls penetrated with the Manhattan distance (in number of rooms) between the AP and Client. The pathloss component depends on type of wall.

$$L_{IWL} = L_{siw}(|x1 - x2| + |y1 - y2|) \tag{2.2}$$

|x1-x2| = Number of walls in x -direction
|y1-y2| = Number of walls in y- direction

2.3.4 Shadowing model:

The shadowing is modeled according to a log-normal distribution with variable standard deviation as function of the connection characteristics. NS-3 considered three main possible scenarios which corresponds to three different standard deviation and mean is always zero.

- outdoor $X_o \approx N(\mu_0, \sigma_0^2)$
- indoor $X_I \approx N(\mu_I, \sigma_I^2)$
- external walls penetration $X_w \approx N(\mu_w, \sigma_w^2)$

NS-3 generates the shadowing values according to the pair of node positions. If the nodes are indoor-outdoor pair or vice-versa.The standard deviation (σ_{IO}) has to be calculated as the square root of the sum of the quadratic values of the standard deviation as the shadowing values are independent of each other

$X_o \approx N(\mu_0, \sigma_0^2)$ and $X_1 \approx N(\mu_1, \sigma_1^2)$
$Z = X_o + X_1 \approx Z(\mu_0 + \mu_1, \sigma_0^2 + \sigma_1^2)$

Where $(\sigma_{\text{IO}} = \sqrt{\sigma_0^2 + \sigma_1^2})$

Frequency	5 GHz
Environment	Urban
City Size	Small
ShadowSigmaOutdoor	7 dBm
ShadowSigmaIndoor	0 dBm
ShadowSigmaExtwalls	8 dBm
Internal Wall loss	5 dBm

Table 2.1: Building model parameters

2.4 Physical layer Parameter:

NS-3 has only one YansWifiPhy channel model for Phy layer. It's Yet Another Network Simulator. This model is responsible for taking packets passed to it from MAC sending then on to YansWiFiChannel.

Initial AP Power	20 dBm
STA power	14 dBm
CCA Threshold	-85 dBm
Channel	Yans Wifi Channel
Channel Number	36
WiFi Phy Std	802.11 ac
Transmitter Gain	0 dBm
Reciever Gain	0 dBm
Short Gard Interval	True (Enable)

Table 2.2: PHY parameters

2.5 Mobility:

The AP and the client position were constant through out the simulation

AP	Constant Position Mobility Model
Client	Constant Position Mobility Model

Table 2.3: Mobility parameters

2.6 Data Link Layer:

The rate using IdealWifiManager get adapted as distance,depending upon the RSSI value between AP and client its an Rate adaptation model in NS-3 apart from MinstrelWifiManager

MAC	HT WiFi MAC
Rate Manager	IdealWifiManager

Table 2.4: Data Link Layer parameters

2.7 WiFi Mac parameter:

2.7.1 AP WiFi Mac

Beacon Interval	100 ms
Beacon Jitter	True(Enable)
QoS Supported	True(Enabled)

Table 2.5: AP WiFi Mac parameters

2.7.2 STA WiFi Mac

Active Probing	False (Disabled)
QoS Supported	True(Enabled)

Table 2.6: STA WiFi MAC parameters

2.8 Transport Layer:

TCP(Transport Control Protocol) application was used with OnOff application for down-link traffic. The data is transferred during On time and there will not be a data transmission during off time. Data packets can be controlled.

On time	1000 sec
Off time	0 sec
MaxByte size	Infinite

Table 2.7: Transport layer parameters

2.9 Simulation Setup:

To know the typical WiFi home coverage the simulation has been done in three different type of home structure. For a given AP deployment the RSSI coverage heat map of home has been calculated.
For throughput coverage the throughput versus RSSI plot was used for fact as the throughput is only function of RSSI i.e. for given RSSI the throughput is fixed which is independent on the channel model , AP and client power or number of rooms in a building. The through put is only function of RSSI.

2.9.1 Throughput as function of RSSI:

To get the Throughput versus RSSI plot the open-space i.e without building model, simulation was done For 1 AP and 1 Client network scenario, where distance between AP and Client kept varying and throughput is calculated. The IdealRateManager was used which adapts the data rate based on the RSSI of client.

AP Power	23 dBm
Client Power	23 dBm
Path loss exponent	3.5
Simulation time	10 sec

Table 2.8: LogDistncePropagation parameters

Figure 2.1 shows the throughput Vs RSSI plot obtained for open space by using LogDistancePropagation model

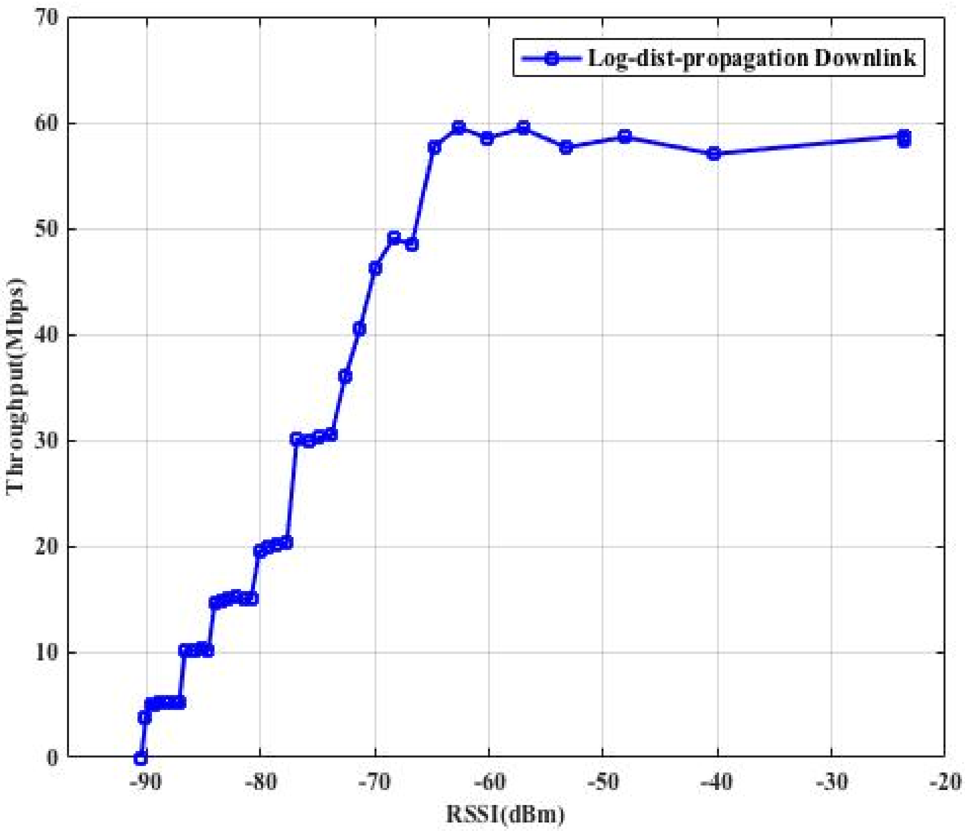

Figure 2.1: LogDistancePropagation model was considered to obtain Throughput versus Received Signal Strength for varying client distance. TCP downlink traffic

2.9.2 Throughput versus RSSI for Different scenario:

To validate throughput is only Function of RSSI,a couple of scenarios were simulated for different network topology. We considered three scenarios which will cover different building structure, different AP power and channel model. In all scenarios only 1 AP and 1 client is used, where client distance kept varying though it was constant.

1. **Building with one long room of dimension 100mX10mX3m:** A building a room of dimension 100mX10mX3m was considered for simulation. AP positioned at coordinates (5,5,1) and throughput for downlink traffic was calculated at different client locations. Client kept at exactly line of sight with AP , client coordinates were (d,5,1) where d kept varying and constant for that particular simulation.
   In this case both AP and client power was 21dBm .

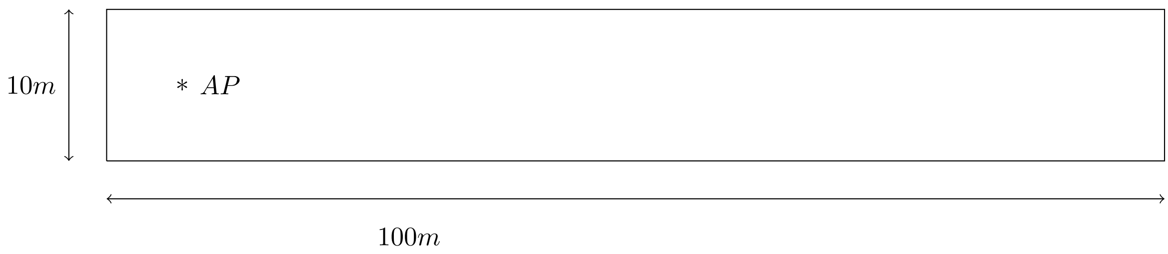

Figure 2.2: 2D top view of Long room of Dimension 100mX10mX3m where AP position at (5,5,1)

2. **Building with 7 rooms:** In this simulation the building has 7 rooms of dimension 10mX10mX3m and AP was kept in first room positioned at (5,5,1).Both AP and client power was kept at 23 dBm. The client position was kept varying and throughput versus RSSI is plotted in this scenario.The TCP downlink traffic considered.

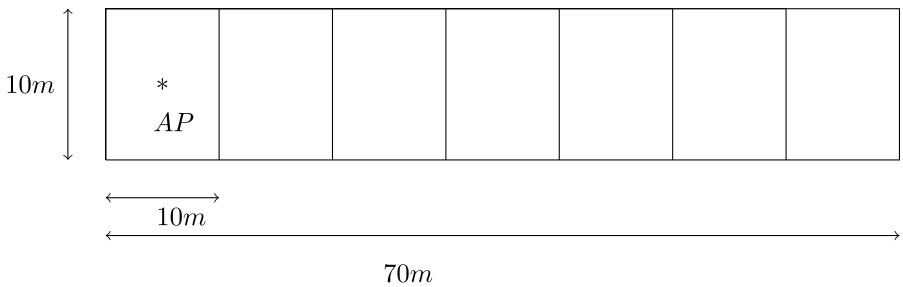

Figure 2.3: 2D top view of 7 room building of Dimension 70mX10mX3m where AP position at (5,5,1)

The through put versus RSSI plot for above scenarios with the open space combined is given below.

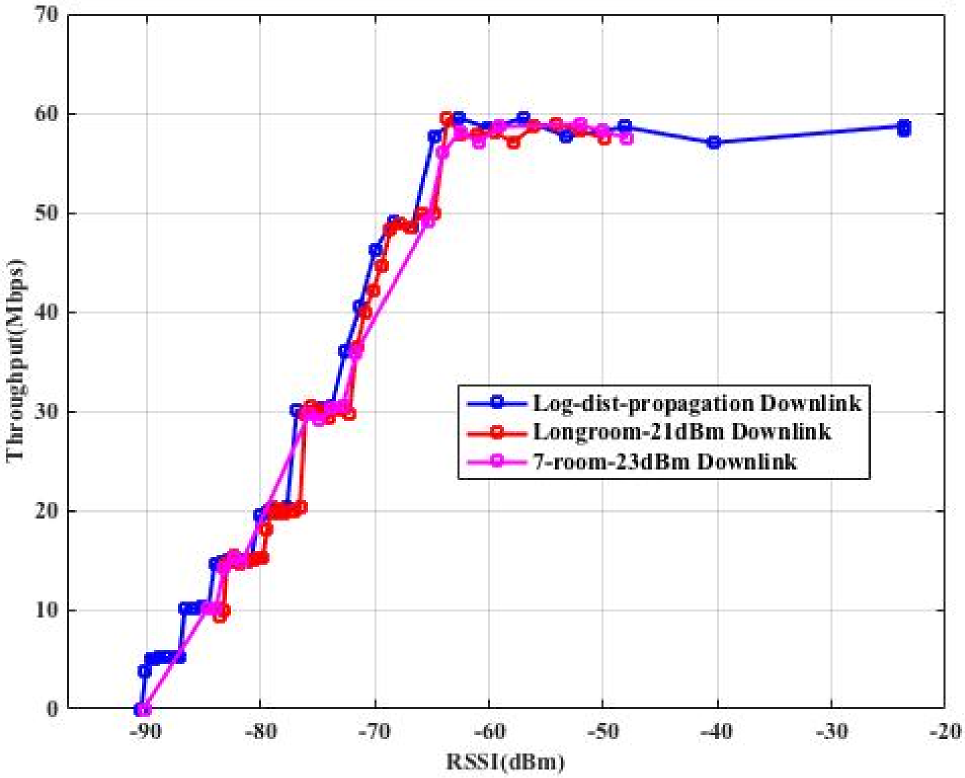

Figure 2.4: Throughput versus RSSI plotted by considering different channel and room condition to validate throughput dependent on RSSI

The figure 2.4 gives the combine plots of throughput versus RSSI for Long distance propagation model, long room building model and Building with seven rooms. The objective of these simulation was to validate the throughput versus RSSI curve given in figure 2.3. from all three plots we can conclude that that throughput is function of RSSI , the throughput versus RSSI curve for all three scenarios are almost same and coincides with each other.

2.9.3 Building Setup:

The simulation was done by considering three different home structure. To know the typical coverage of home WiFi. For given location of AP the client coordinates is varied by 25cm each time and RSSI seen by client was computed. The AP location is kept constant and client location was varied but constant for given simulation. The RSSI heat map was obtained from ITU-R1238 equation. From given RSSI the throughput was calculated from the Throughput versus RSSI curve. And heat map of throughput was plotted from RSSI values.

To calculate RSSI the following ITU-R1238 building propagation equation was used as both nodes AP and clients are inside the building.

- **RSSI equation:**

  $$RSSI = AP_{power} - Loss \tag{2.3}$$

  same floor:

  $$Loss = 20log_{10}(5180) + 28log_{10}(d) + 5 * R - 28[dB] \tag{2.4}$$

  different floors:

  $$Loss = 20log_{10}(5180) + 28log_{10}(d) + 5 * R + 4n - 28[dB] \tag{2.5}$$

  Where
  d = Euclidean distance between Client and AP.
  R = Manhattan's distance i.e. room difference between client and AP.
  n = Floor difference between client and AP.

The building dimensions of three homes which was used to analyze the coverage is as follows.

- **2-BHK:** The home used was of dimension 12mX10mX3m and it has four rooms
- **4-BHK:** 4-BHK home has dimension of 18mX10mX3m and it has six rooms
- **Duplex Home:** Duplex house has dimension of 12mX5mx3m of two floors and four rooms

Room Dimension	6mX5mX3m
Floors	1
Building Type	Residential
Wall Type	Concrete with windows
Rooms in X direction	2
Rooms in Y direction	2

Table 2.9: 2-BHK home parameters

Room Dimension	6mX5mX3m
Floors	1
Building Type	Residential
Wall Type	Concrete with windows
Rooms in X direction	3
Rooms in Y direction	2

Table 2.10: 4-BHK home parameter

Room Dimension	5mX6mX3m
Floors	2
Building Type	Residential
Wall Type	Concrete with windows
Rooms in X direction	2
Rooms in Y direction	1

Table 2.11: Duplex home parameter

2.10 Home RSSI coverage Heat map and Throughput Heat map:

The building structure of three homes which were used to analyze the coverage are given below.

2.10.1 2-BHK home structure

The 2-BHK home has typically 4 rooms of size 6mX5mX3m height of building was 3m. All rooms are of equal size which makes the building total dimension of 12mX10mX3m. for given home the AP is fixed at given position , and client coordinates are varied so as to cover the entire home.
AP kept 1m from ground level every time and also 1 m from ground level RSSI seen by client was obtained by RSSI equation (2.3) as this home structure has only one floor so loss calculation wont count floor loss.

Building structure and AP locations of 2-BHK given below

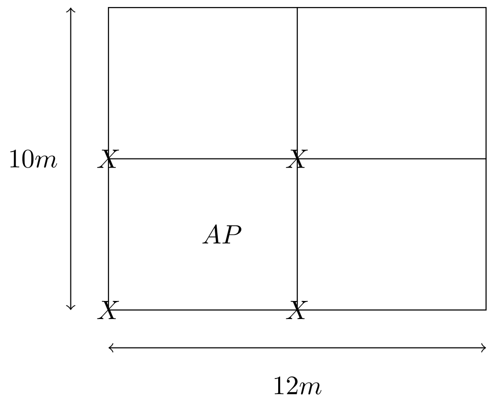

Figure 2.5: 2D top view of 2-BHK home with AP locations

The AP was kept at the extreme corner of the room to know the typical coverage of house. For each AP location the RSSI heat map and the throughput heat map from that RSSI heat map was obtained

- **AP location at (0,0,1):**

The RSSI heat map for given location of AP as follow.

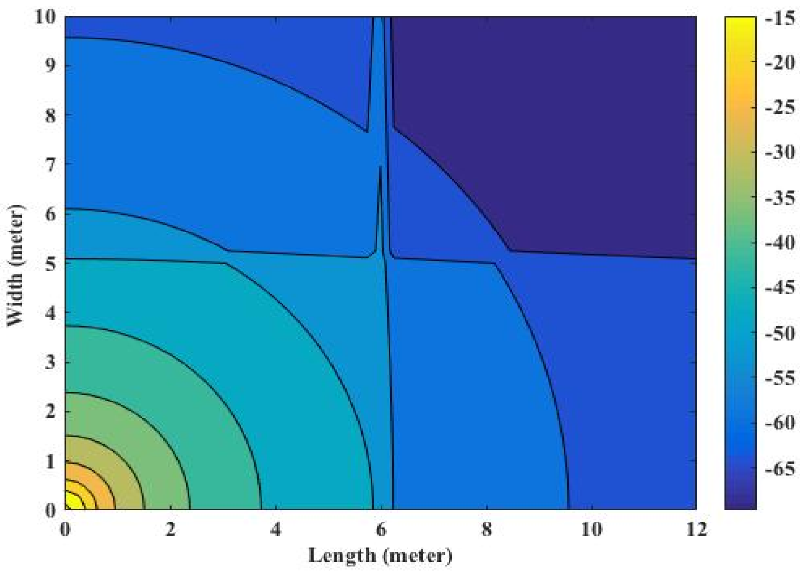

Figure 2.6: RSSI heat map of 2BHK home for AP at (0,0,1)

The RSSI values varies from -15dBm to nearly -67dBm when client is close to AP the RSSI value seen by client is -15dBm when client was exactly opposite to the AP i.e when client in other room corner at location 12,10,1 the client experiences poor throughput.

The throughput heat map for given location of AP

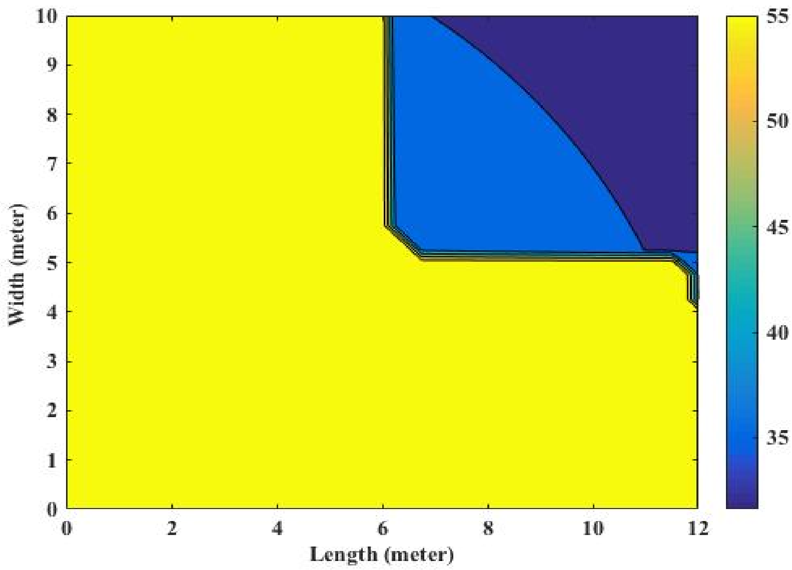

Figure 2.7: Throughput heat map of 2BHK home for AP at (0,0,1)

The throughput range for a given location of AP is varies from 55 Mbps to 28-29 Mbps. Throughput coverage of 50 Mbps for almost 3 rooms. When client was right-most room it experiences the lower throughput as it has to go through path loss of two walls from AP. Other two rooms experiences only one wall path loss.

- **AP location at (6,0,1):**

The RSSI heat map for given location of AP as follow.

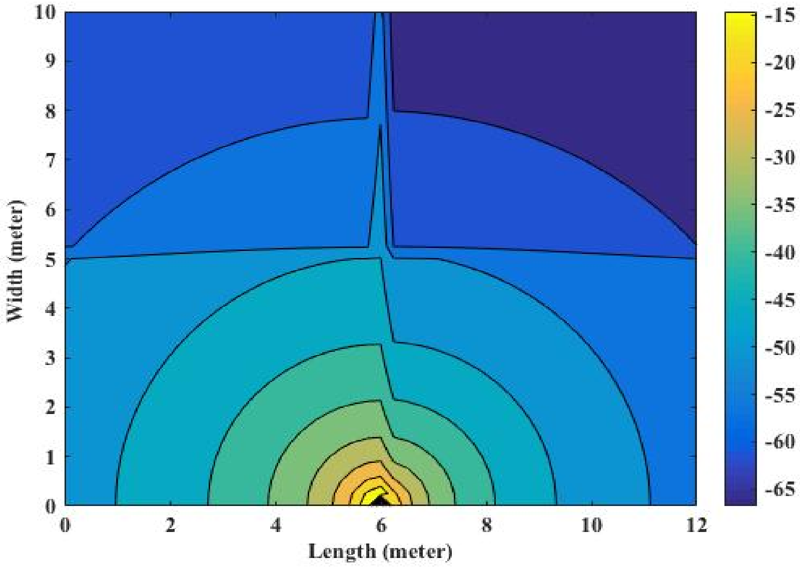

Figure 2.8: RSSI heat map of 2BHK home for AP at (6,0,1)

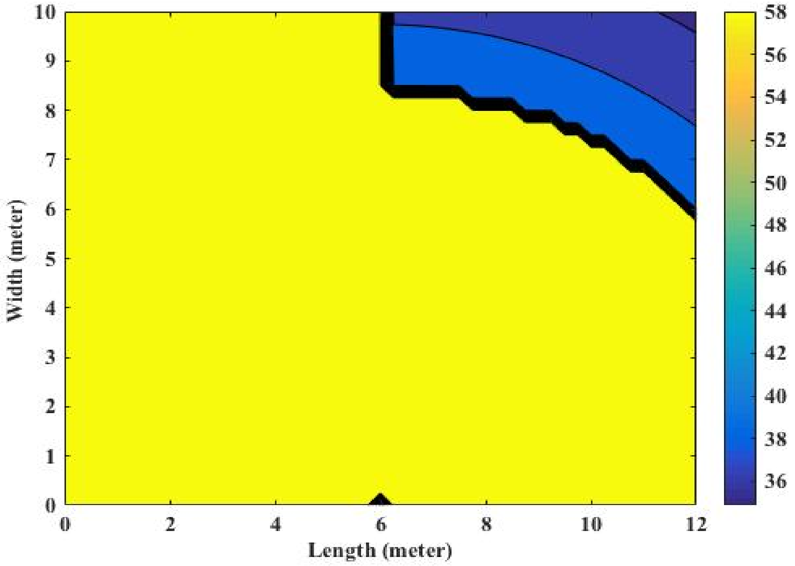

Figure 2.9: Throughput heat map of 2BHK home for AP at (6,0,1)

The RSSI coverage for given AP location is from -15dBm to -65dBm the right most room has poor RSSI coverage for give AP location.
Throughput coverage for a given AP location is varies from 57Mbps to 35Mbps the the throughput in rightmost room is lesser compared to other rooms because of poor RSSI. The RSSI and Through put coverage is fairly good.

- **AP location at (0,5,1):**

The RSSI heat map for given location of AP as follow.

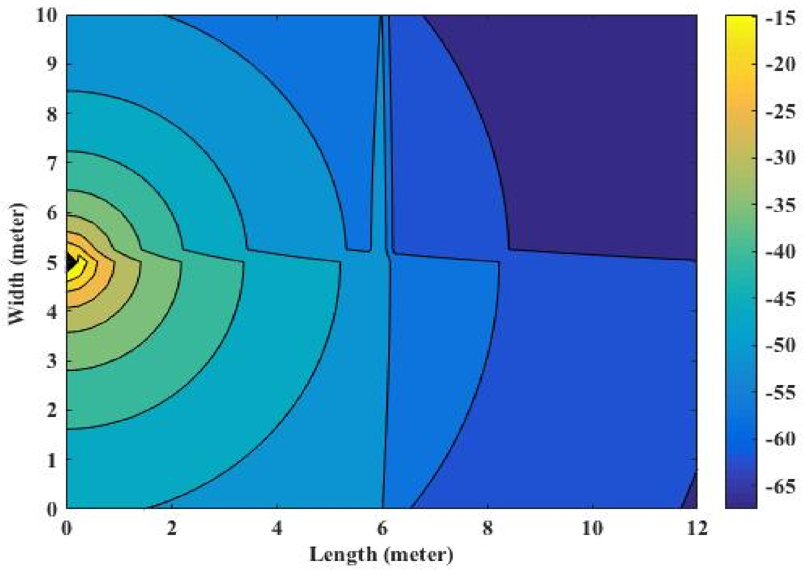

Figure 2.10: RSSI heat map of 2BHK home for AP at (0,5,1)

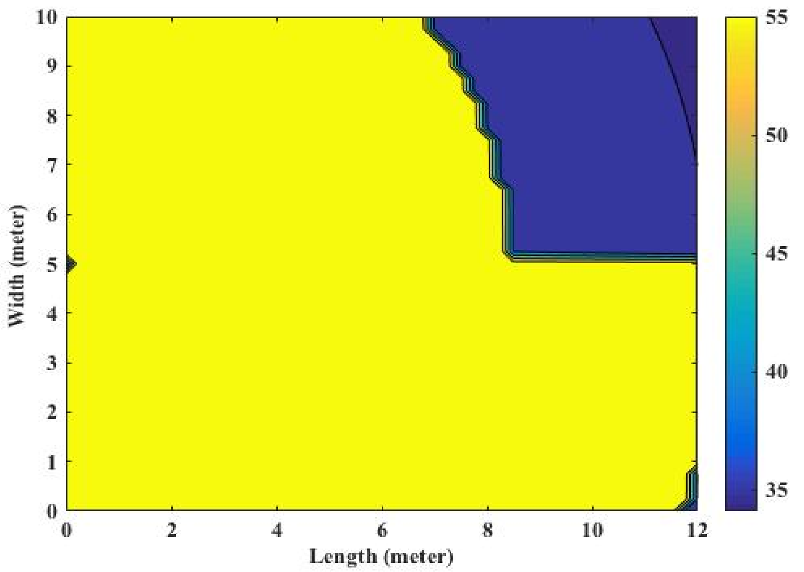

Figure 2.11: Throughput heat map of 2BHK home for AP at (0,5,1)

The RSSI coverage in above heat map varies from -15 dBm to -67 dBm , the RSSI coverage in right most room is poor compared to other rooms.
Throughput range for given location of AP varies from 55 Mbps to 37 Mbps , rightmost room has poor throughput.

- **AP location at (6,5,1):**

The RSSI heat map for given location of AP as follow.

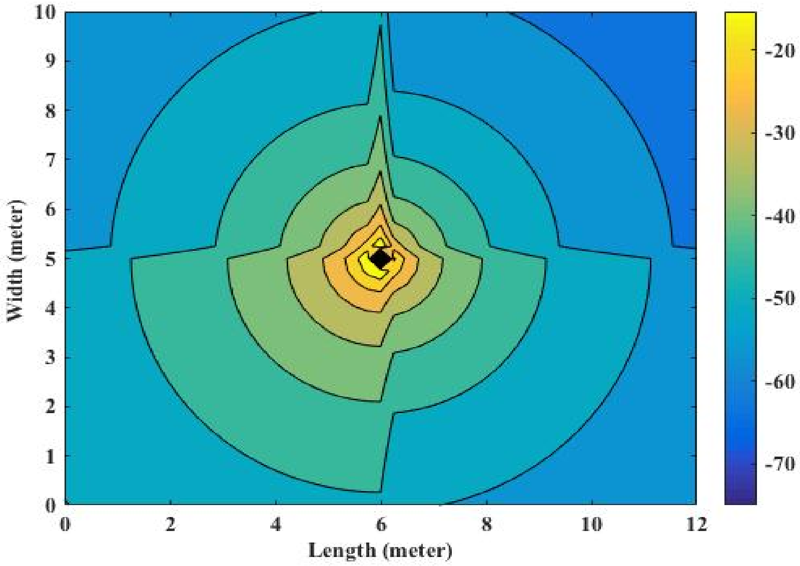

Figure 2.12: RSSI heat map of 2BHK home for AP at (6,5,1)

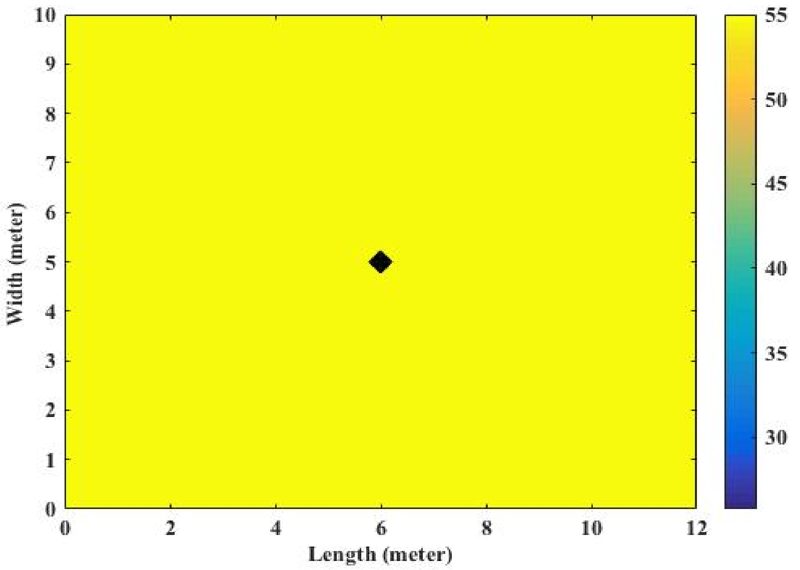

Figure 2.13: Throughput heat map of 2BHK home for AP at (6,5,1)

RSSI coverage for given location of AP varies from -15 dBm to -55dBm , This location of Ap has good coverage of RSSI as it was centre of home.
Entire home has throughput of nearly 55 Mbps to 57 Mbps
The AP location at center of home has given very good coverage of RSSI and throughput.

2.10.2 4-BHK home structure:

The 4-BHK home has total 6 rooms, each room has dimension of 6mX5mX3m and overall dimension of home would be 18mX10mx3m. and all rooms are of equal size. Here 7 AP location has considered to know the best coverage of RSSI and throughput. AP and client kept 1m from ground.

4-BHK home structure and AP location

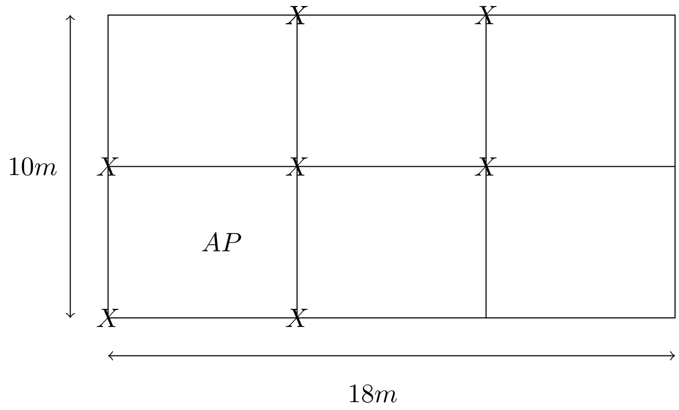

Figure 2.14: 2D top view of 4-BHK home with AP locations

The cross marks gives the location of AP . For each location of AP the RSSI coverage and throughput is computed. The home has one floor with six rooms

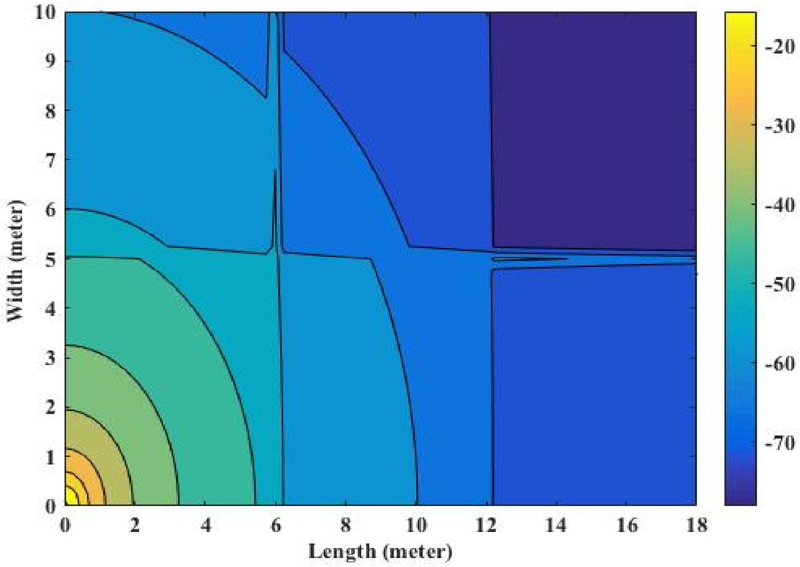

Figure 2.15: RSSI heat map of 4BHK home for AP at (0,0,1)

- **AP location at (0,0,1):**

The RSSI heat map for given location of AP as follow.

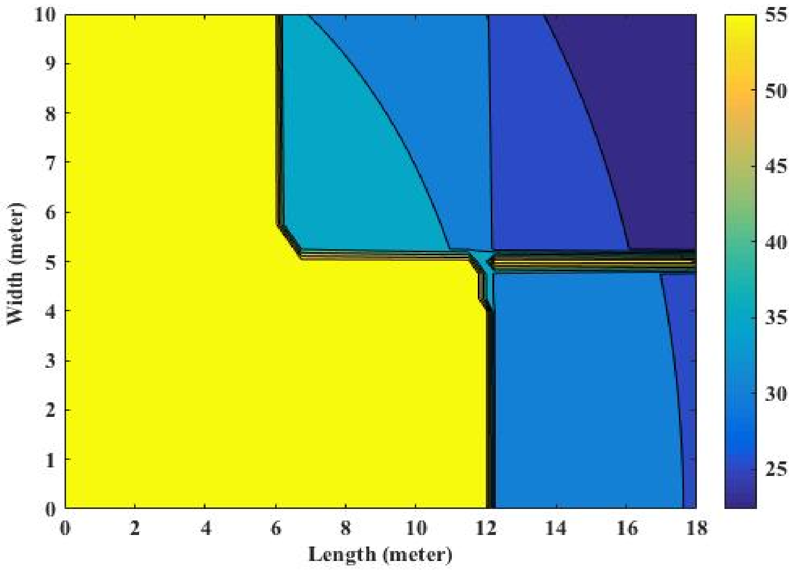

Figure 2.16: Throughput heat map of 4BHK home for AP at (0,0,1)

For given location of AP the RSSI coverage varies from -15 dBm to -73 dBm .The rightmost corner has poor coverage of RSSI. The rightmost room experiences path loss of 3 walls. The throughput varies from 57 Mbps to 20 Mbps. rightmost room has lower throughput coverage. For given location of AP three rooms (which are in yellow colors) experiences throughput of 55 Mbps.

- **AP location at (0,5,1):**

The RSSI heat map for given location of AP as follow.

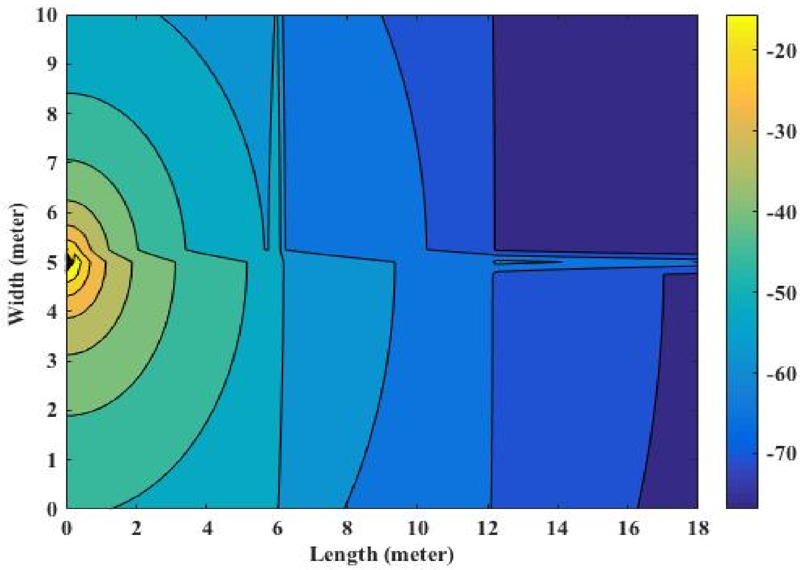

Figure 2.17: RSSI heat map of 4BHK home for AP at (0,5,1)

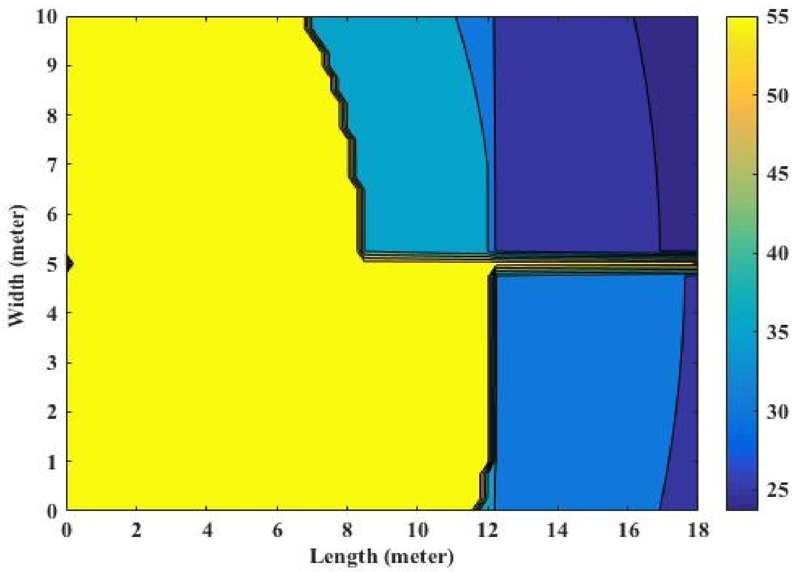

Figure 2.18: Throughput heat map of 4BHK home for AP at (0,5,1)

For given location of AP the RSSI ranges from -15 dBm to -73 dBm . Right most rooms experiences poor RSSI and throughput ranges from 57 Mbps to 23 Mbps - 21 Mbps. Rightmost rooms has poor throughput coverage. More than 3 rooms has good coverage of 55 Mbps.

- **AP location at (6,0,1):**

The RSSI heat map for given location of AP as follow.

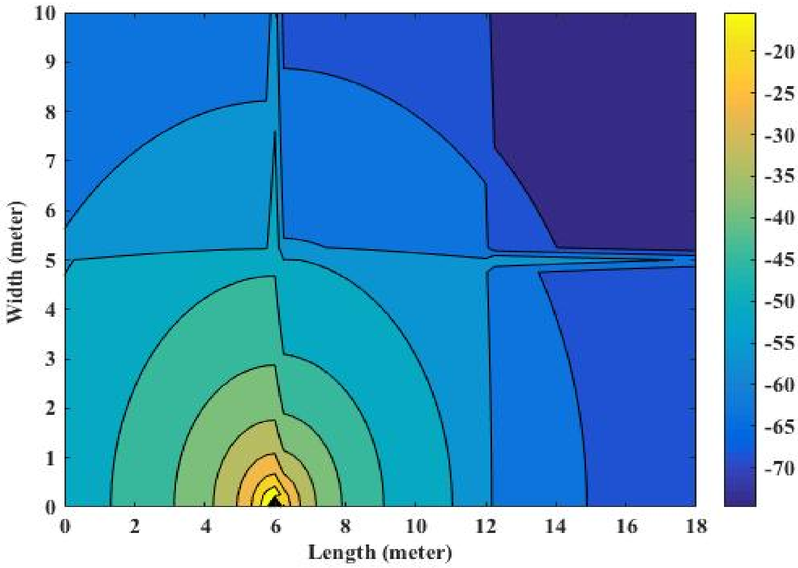

Figure 2.19: RSSI heat map of 4BHK home for AP at (6,0,1)

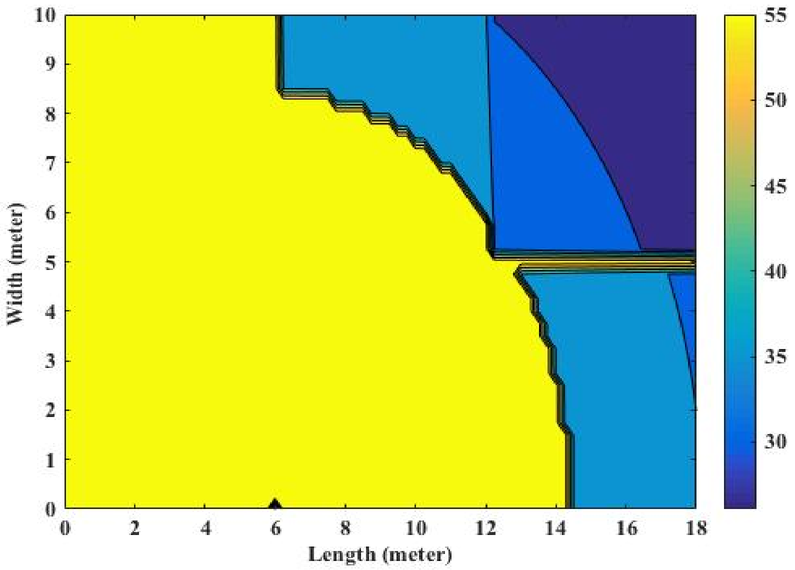

Figure 2.20: Throughput heat map of 4BHK home for AP at (6,0,1)

The coverage of RSSI for given location ranges from -15 dBm to -73 dBm and throughput has coverage of 55 Mbps to 25 Mbps. Some part of rightmost rooms experiences poor coverage of throughput.

- **AP location at (6,5,1):**

The RSSI heat map for given location of AP as follow.

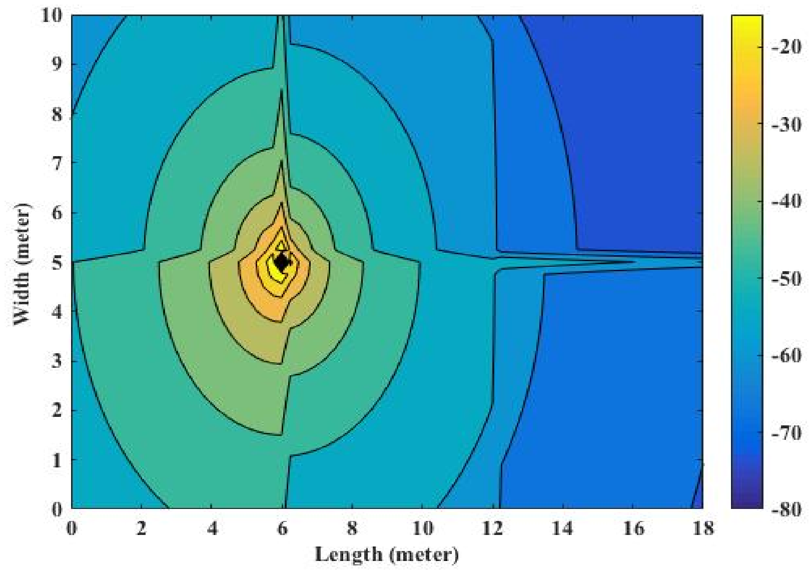

Figure 2.21: RSSI heat map of 4BHK home for AP at (6,5,1)

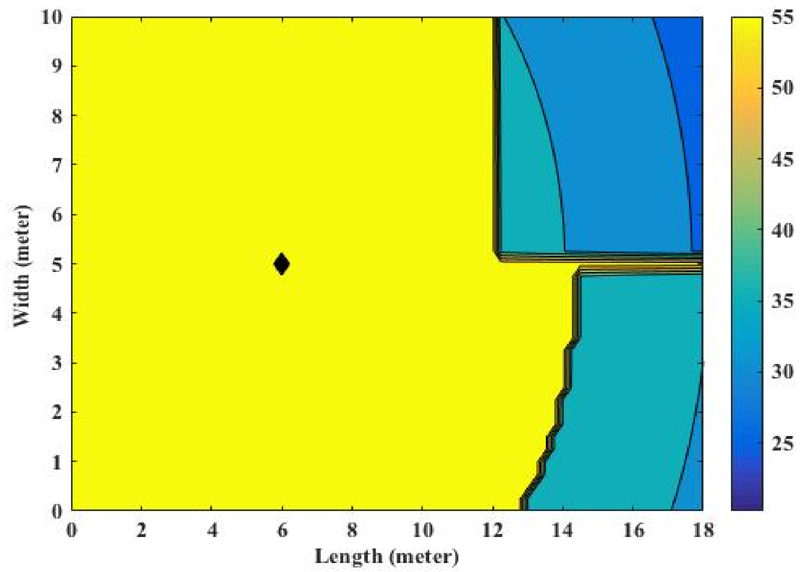

Figure 2.22: Throughput heat map of 4BHK home for AP at (6,5,1)

The throughput coverage for given location of AP varies from 55 Mbps to 31 Mbps . More than 4 rooms has throughput coverage of 55 Mbps for a given location of AP.

- **AP location at (12,5,1):**

The RSSI heat map for given location of AP as follow.

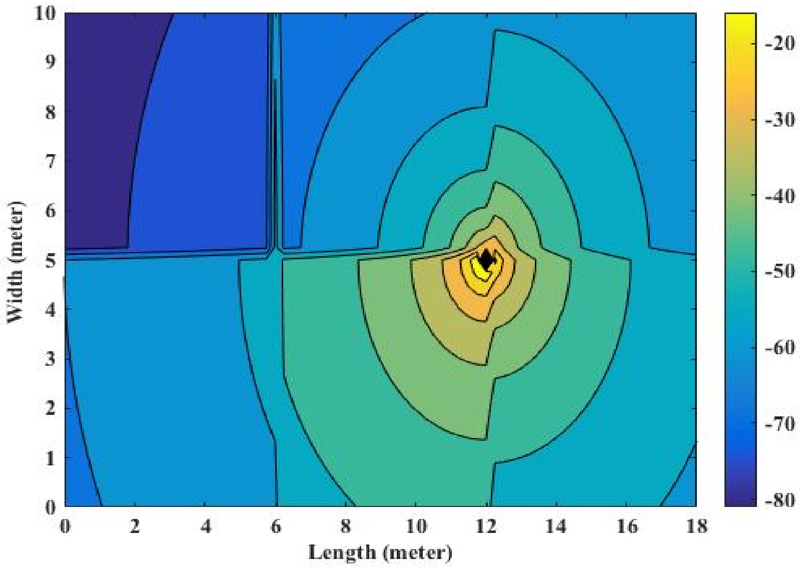

Figure 2.23: RSSI heat map of 4BHK home for AP at (12,5,1)

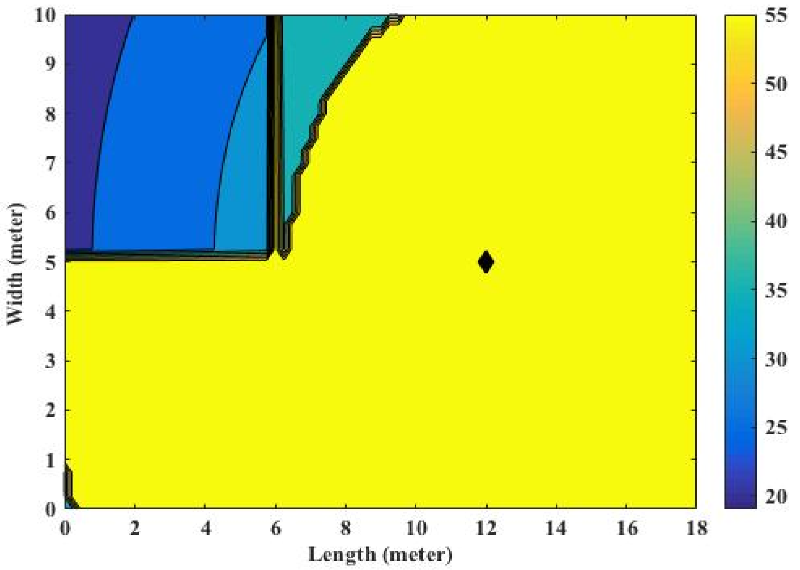

Figure 2.24: Throughput heat map of 4BHK home for AP at (12,5,1)

The RSSI coverage for given location of AP varies from -15 dBm to nearly -79 dBm.Part of left most room has poor coverage of RSSI. The throughput range varies from 55 Mbps to 20 Mbps for gievn AP location and part of left most room has poor throughput coverage.

- **AP location at (6,10,1):**

The RSSI heat map for given location of AP as follow.

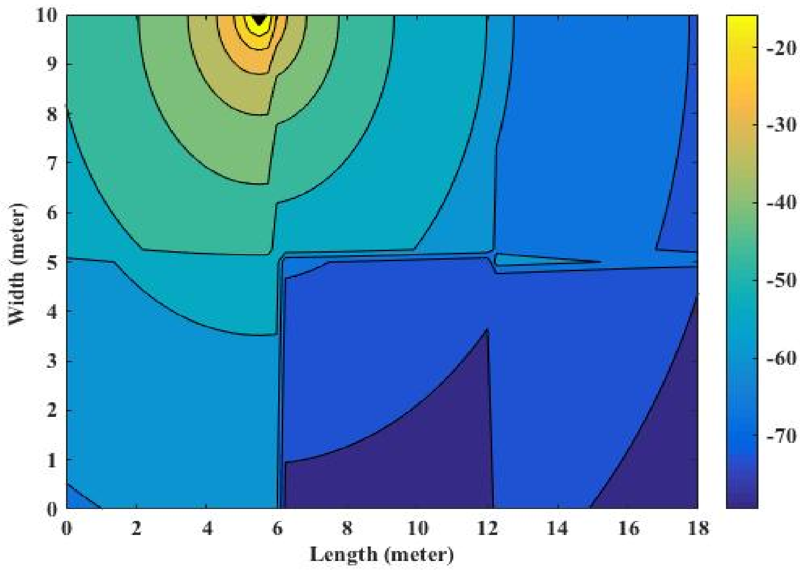

Figure 2.25: RSSI heat map of 4BHK home for AP at (6,10,1)

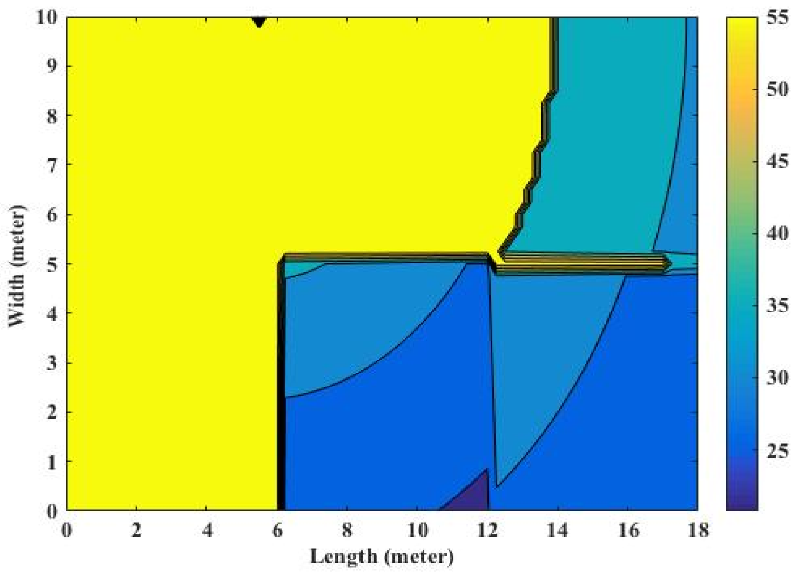

Figure 2.26: Throughput heat map of 4BHK home for AP at (6,10,1)

For given location of AP the RSSI ranges from -15 dBm to -76 dBm. The throughput coverage varies from 55 Mbps to 21 Mbps. More than three rooms has throughput coverage of 55 Mbps for a given location of AP.

- **AP location at (12,10,1):**

The RSSI heat map for given location of AP as follow.

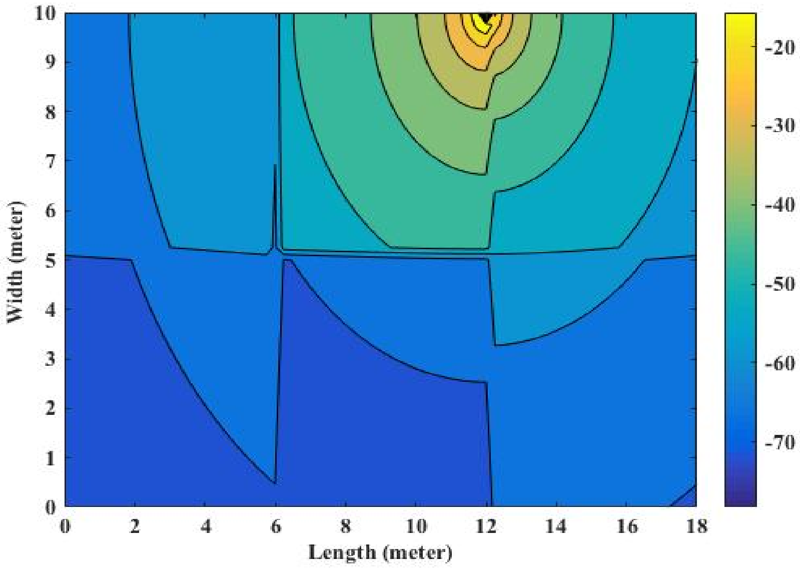

Figure 2.27: RSSI heat map of 4BHK home for AP at (12,10,1)

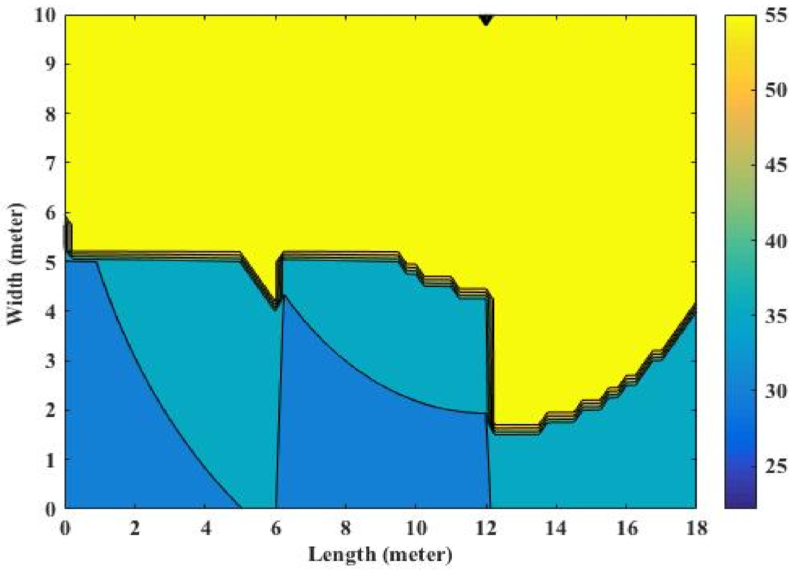

Figure 2.28: Throughput heat map of 4BHK home for AP at (12,10,1)

For given location of AP the RSSI coverage ranges from -15 dBm to -65 dBm and throughput has ranges from 55Mbps to 30 Mbps. More than three rooms has 55Mbps of throughput coverage.

2.10.3 Duplex home structure:

Duplex home structure has two floors with two rooms in each floors. Each room has dimension of 5mX6mX3m over all dimension of home would be 10mX6mX3m.Two AP location has been considered as shown in figure by cross mark to know the typical coverage of home. For calculation of RSSI the floor path loss equation has been considered as it has two floors structure.

Building structure and AP location

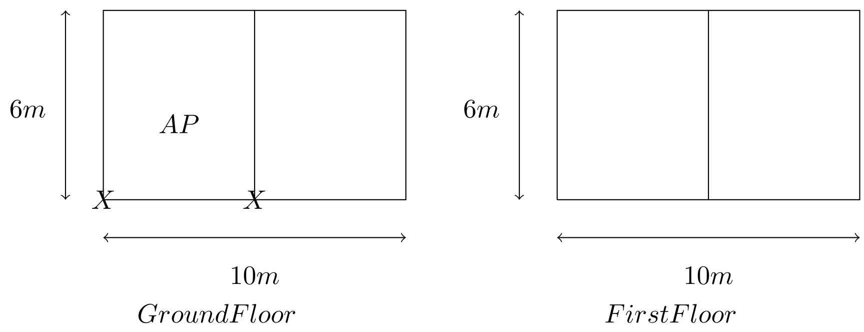

Figure 2.29: 2D top view of Duplex home with AP locations

Both AP and client positioned 1m from floor level RSSI heat map and Throughput heat map for above locations of AP's are given below.

- **AP location at (0,0,1):**

The RSSI heat map for given location of AP as follow.

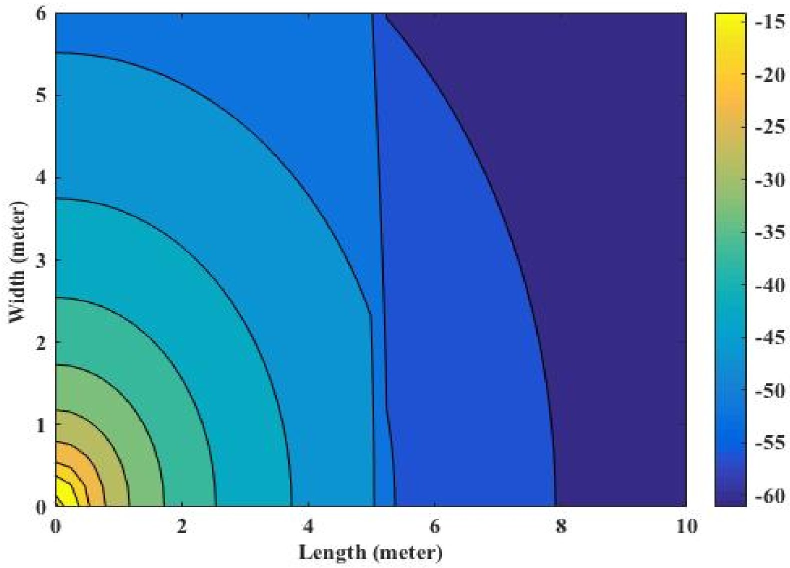

Figure 2.30: RSSI heat map for Ground floor of duplex home, AP at (0,0,1)

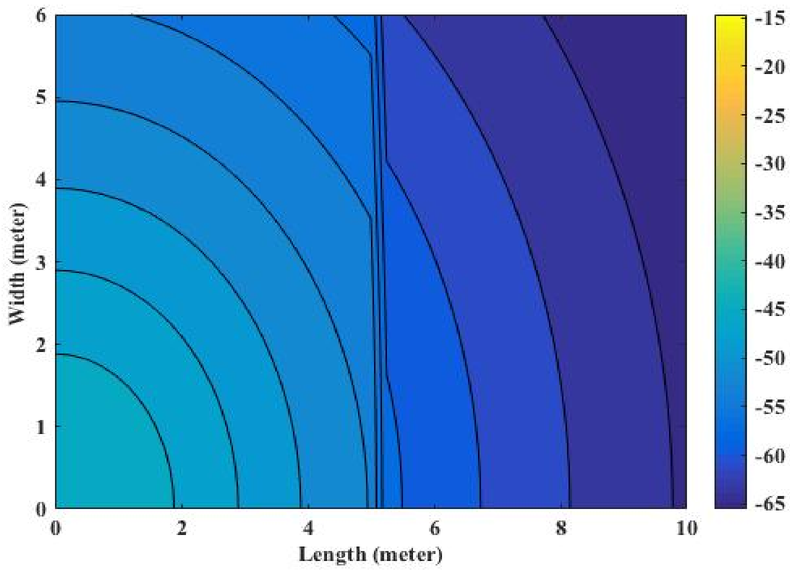

Figure 2.31: RSSI heat map for first floor of duplex home, AP at (0,0,1)

Above two figures gives the typical coverage of RSSI of two floor room for AP location (0,0,1). RSSI range of ground level rooms varies from -15 dBm to -59 dBm and first floor has coverage of -45 dBm to -65 dBm.

- **AP location at (0,0,1):**

The Throughput heat map for given location of AP as follow.

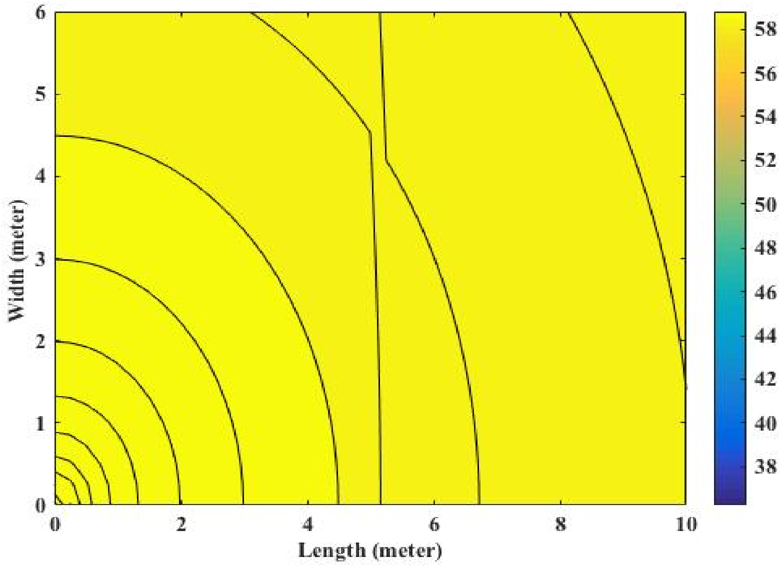

Figure 2.32: Throughput heat map for Ground floor of duplex home, AP at (0,0,1)

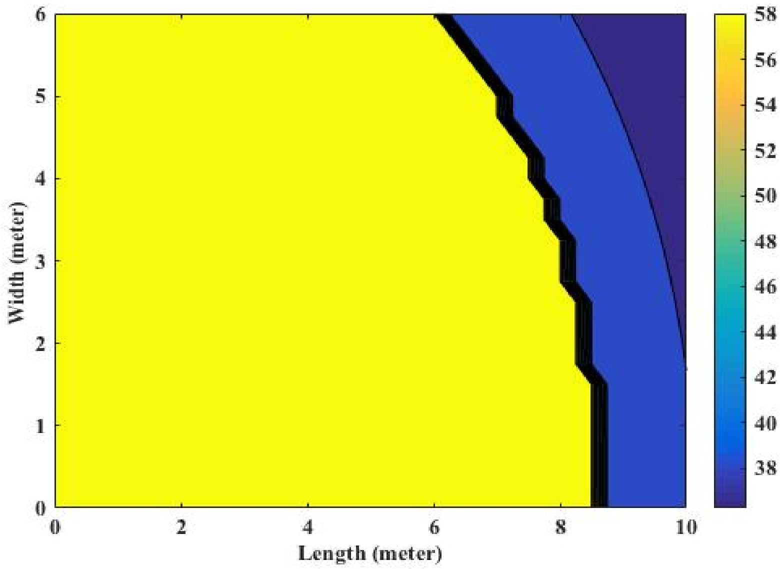

Figure 2.33: Throughput heat map for first floor of duplex home, AP at (0,0,1)

The above two figure give the throughput coverage for AP location (0,0,1) . Entire ground level rooms has throughput near about 56 Mbps and first floor has throughput range from 57 Mbps to 35 Mbps , some part of right room has throughput near about 35 Mbps

- **AP location at (5,0,1):**

The RSSI heat map for given location of AP as follow.

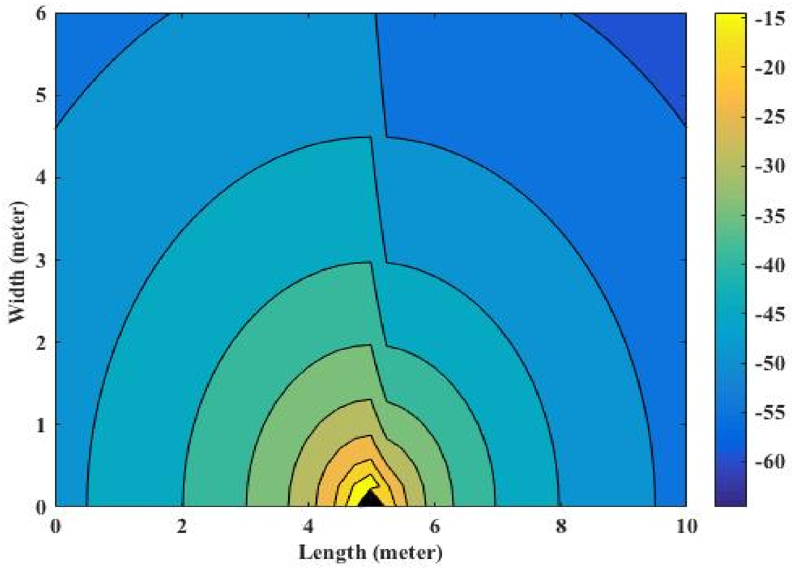

Figure 2.34: RSSI heat map for Ground floor of duplex home, AP at (5,0,1)

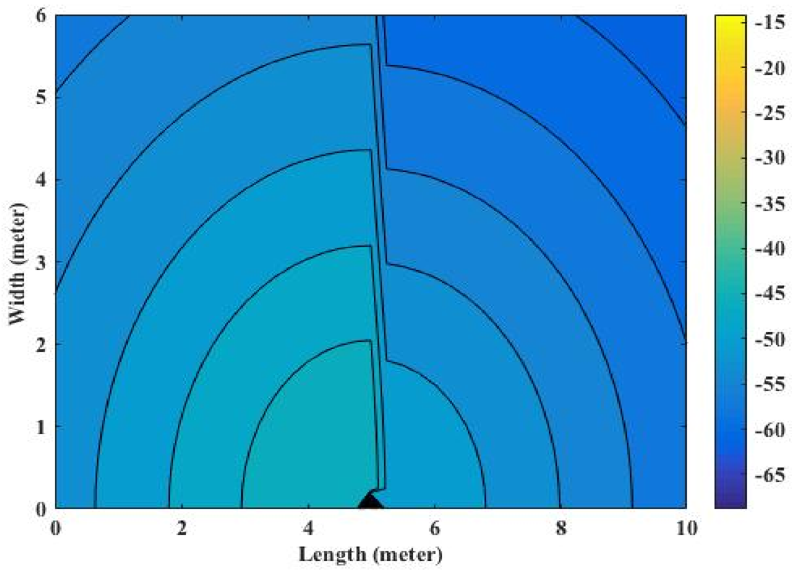

Figure 2.35: RSSI heat map for first floor of duplex home, AP at (5,0,1)

The above both figure gives the RSSI coverage for AP location (5,0,1). The RSSI range varies from -15 dBm to -53 dBm in ground floor and from -40 dBm to -57 dBm for first floor.

- **AP location at (5,0,1):**

The throughput heat map for given location of AP as follow.

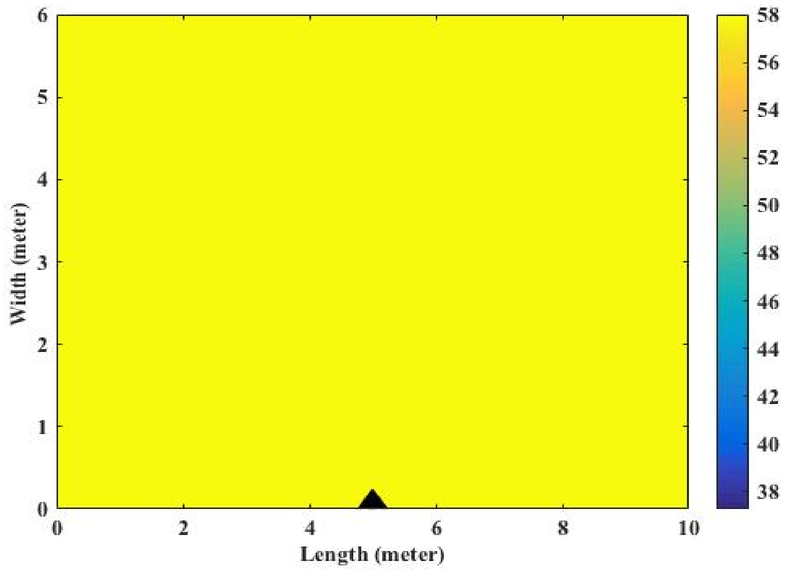

Figure 2.36: Throughput heat map for Ground floor of duplex home, AP at (5,0,1)

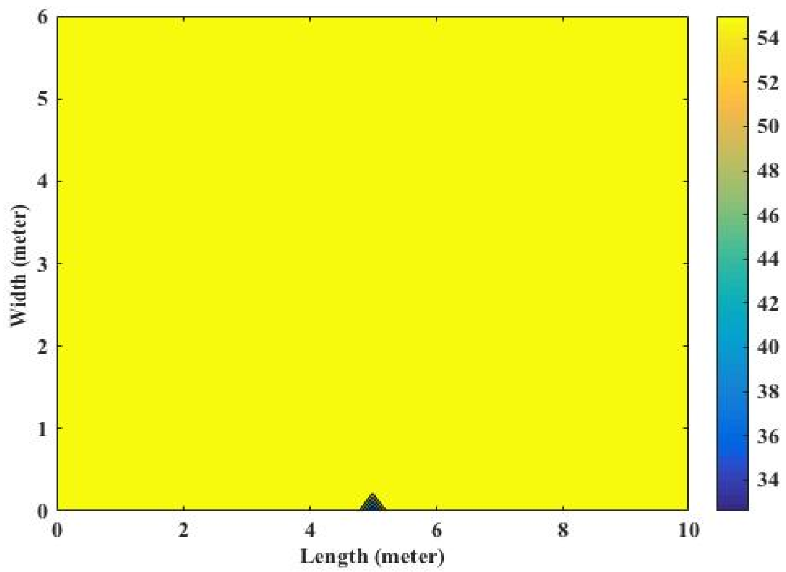

Figure 2.37: Throughput heat map for first floor of duplex home, AP at (5,0,1)

The above two figure gives throughput coverage for AP location (5,0,1). Entire two floor has nearly 54 Mbps throughput coverage.

CHAPTER 3

Performance evaluation of Dense Network

3.1 Introduction

Objective is to study the performance of WiFi in dense network scenario. As apartment housing structure are increasing in urban cities, We tried to evaluate the performance of WiFi by considering an apartment structure. The motto of these simulation is to know the performance of WIFi for typical apartment housing scenarios to know the effect of n number of client to a single AP and effect of AP interference in adjacent house in an apartment. Effect of AP power on downlink and uplink aggregate throughput has plotted and studied the effect of CCA threshold on downlink aggregate throughput.

As nodes were indoor ITU-R1238 path loss propagation model was considered. User Datagram Protocol(UDP) has been used for Downlink and uplink traffic.

3.2 Building Structure And Node positions

The building structure which considered for performance evaluation has two floors. Each floor consists of eight 2-BHK homes. 2-BHK home has four rooms with dimension 6mX5X3m of each room , all four rooms were of same dimension. Ground floor has two row houses . Each row has four 2-BHK home structure. And same structure has been followed for first floor. In total apartment structure has 16 2-BHK homes. 2-BHK building parameters were same as listed in Table 2.9 in chapter 2.

Each home has one AP and four clients i.e each room in home has one client. AP position was constant throughout the simulation , AP was kept at leftmost corner in home. The clients positions were randomly placed in each room and those were constant throughout simulation. 20 MHz band width channel was used for simulation.The hybrid building parameters, path loss model parameters were same as mentioned in chapter 2. Transport layer parameter were different as UDP protocol has been used to perform simulations.

- **Transport Layer parameter:**

For downlink and uplink traffic User Datagram Protocol (UDP) application was used. The traffic was generated by using OnOffHelper. During On time data has been transferred and No data is transmitted during off time.

Maximum Data Rate	100 Mbps
On time	1000 sec
Off time	0 sec
Maximum Packet size	Infinite

Table 3.1: Transport layer parameters

- **Building Structure**

The Dense scenario Building structure as follows

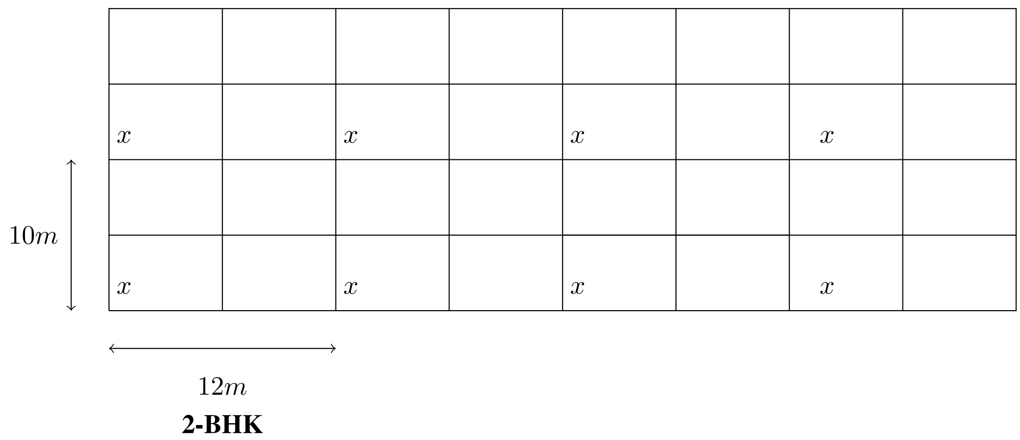

Figure 3.1: 2D top view of ground floor structure of building with AP location in each home

The above figure gives the 2-D top view of building's ground floor structure. Each 2-BHK home has one AP at left most corner as shown in figure. The client position was randomly placed with one client in each room. All four clients in each home was associated with a AP of that particular home.

3.3 Performance Evaluation

The performance measure used for studying is throughput. Throughput is the amount of data transmitted in one second. Unit used for throughput in this simulation is Mbps.

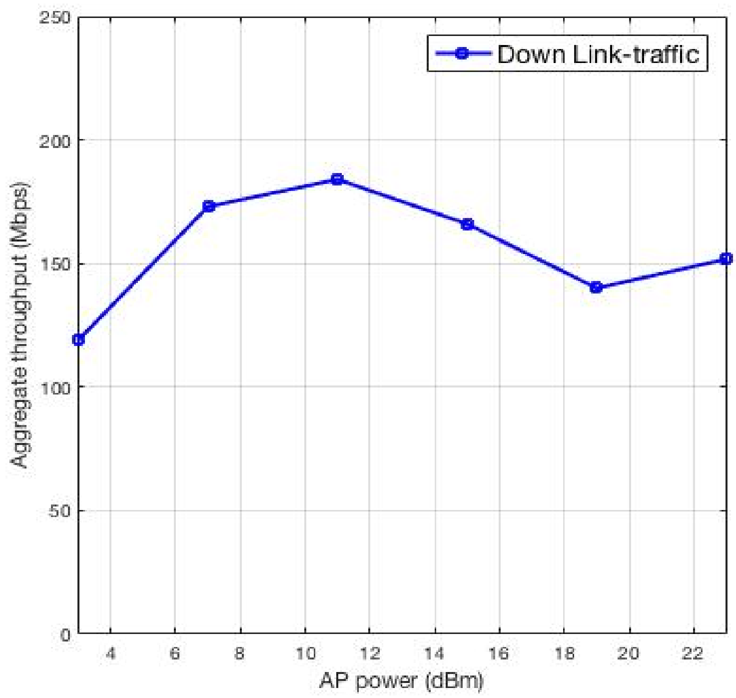

Figure 3.2: Aggregate Throughput versus Access Point power for downlink traffic

The above figure illustrates the effect of AP power on aggregate downlink throughput. Here all client power kept at 14 dBm and AP power was varied from 3 dBm to 23 dBm. The aggregate throughput decreases from AP power 23 dBm to 19 dBm . And throughput keeps on increasing till AP power reaches 11 dBm it is because of spacial reuse. As AP power decreases the spacial reuse increases. But after 11 dBm AP power throughput decreases because of insufficient power of AP to connect to the client. Aggregate downlink throughput was maximum at AP power level of 11 dBm.

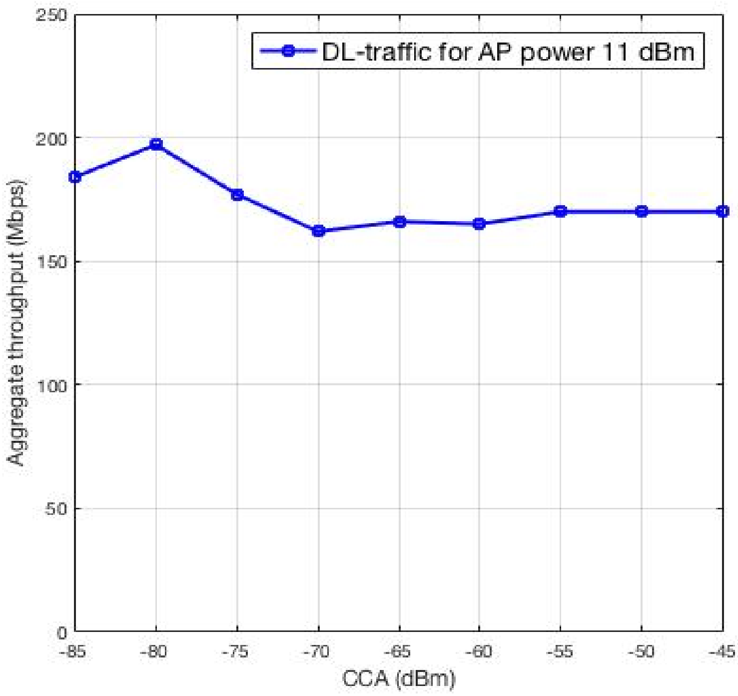

Figure 3.3: Aggregate Throughput versus Clear Channel Assessment(CCA) value for downlink traffic

Figure 3.3 shows the effect of Clear Channel Assessment(CCA) value on aggregate downlink throughput. CCA is a mechanism for determining whether the medium is idle or not. The AP power is kept at 11 dBm and client power at 14 dBm. The aggregate throughput observed to be higher at CCA value of -80 dBm. as value negatively decreases the aggregate throughput remains constant.

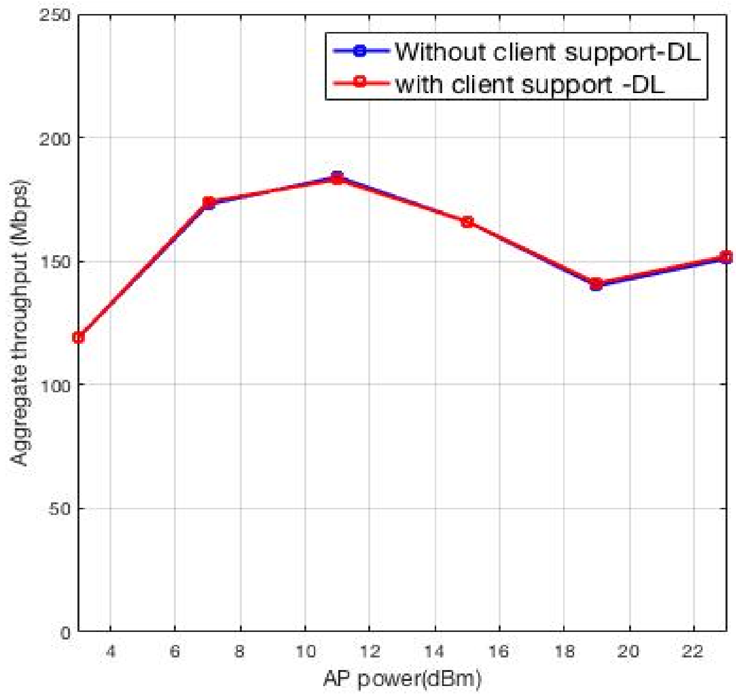

Figure 3.4: Aggregate Throughput versus AP power with client support for downlink traffic

The above figure gives the effect of client power support for downlink traffic. The objective was to study the effect of client power on downlink traffic. In the earlier plots client power fixed at 14dBm but in this simulation the client power was minimum of 14 dBm and the power of AP to which client was associated. The figure shows client power adaptation did not have much effect on aggregate throughput for downlink traffic.

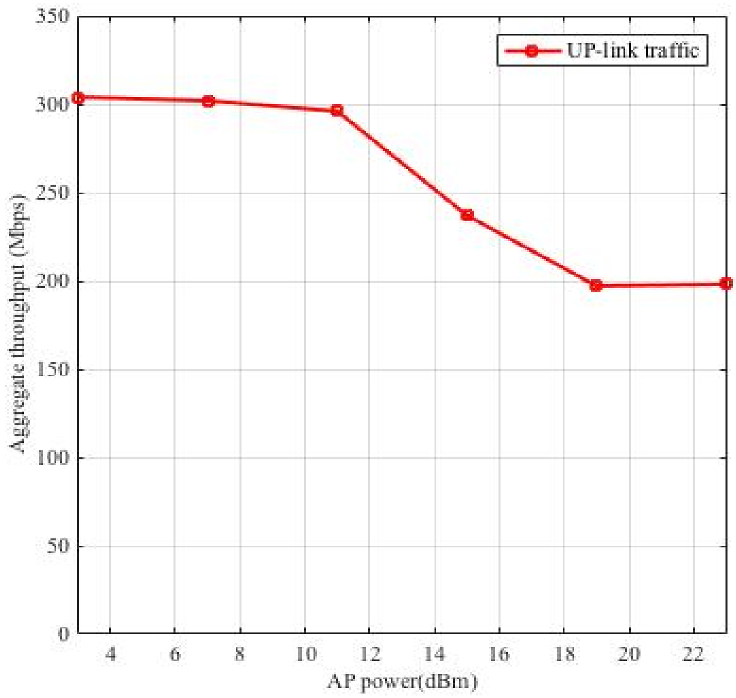

Figure 3.5: Aggregate Throughput versus Access point power for Uplink traffic

The figure shows the effect of AP power on aggregate uplink throughput. The simulation has done by changing the AP power.The client power also kept same as AP power during simulation. The throughput has increased rapidly between 19 dBm to 11 dBm . After 11 dBm the throughput was observed to be constant.

CHAPTER 4

Conclusions

The home WiFi coverage simulations were helpfull to find the optimal AP deployment.

- In case with 2-BHK home structure the AP deployed at position (6,5,1) gave best coverage in terms of throughput.
- For 4-BHK home structure the AP deployed at location (12,5,1) and (12,5,1) gave the better coverage
- For duplex home structure a AP deployed at location (5,0,1) gave best coverage.

In dense network scenario the performance evaluation of WiFi gave an idea of optimal value of AP power for better results in terms of throughput.

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[2]. NS-3 Building model- https://www.nsnam.org/docs/release/3.14/models/html/buildings.html

[3]. NS-3 wifi model - https://www.nsnam.org/docs/models/html/wifi.html

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